ORIGINAL ARTICLE

Development of Laparoscopic Donor Nephrectomy: A Strategy to Increase Living Kidney Donation Incentive and Maintain Equivalent Donor/Recipient Outcome

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Background/Purpose: Laparoscopic donor nephrectomy (LDN) has emerged as the preferred technique worldwide, and has contributed to a dramatic increase in living kidney donation during the past decade. We adopted LDN in 2002 with the intention of increasing living kidney donation incentive and maintaining equivalent donor/recipient outcome.

Methods: Forty-five LDNs were performed between September 2002 and November 2007. Donor demographics, operative characteristics, perioperative complications and donor/recipient outcome were reviewed retrospectively. The LDN series was divided into earlier and later groups for comparison. To confirm the safety and efficacy of LDN, we compared the results with those of previous series and our open donor nephrectomy (ODN) series.

Results: All 45 LDN kidneys were procured and transplanted successfully. Mean donor operation time was 327.7 ± 10.2 minutes, blood loss was 286.0 ± 48.3 mL, and warm ischemia time was 233.9 ± 19.6 seconds. Two (4.4%) open conversions happened in the earlier group. There was a significant decrease in warm ischemia time and donor intraoperative complications in the later group. There was no donor mortality and there were no repeat surgical procedures. Delayed graft function occurred in 8.9% of cases and three (6.7%) recipients developed ureteral complications. All but one recipient was discharged with adequate renal function. Graft function continued in 41 of the 43 harvested kidneys (95.3%). Compared with ODN, there was a significant decrease in donor postoperative stay in the LDN series ($p = 0.00$). There was no difference between the series with regard to donor safety, donor outcome, and immediate and long-term recipient outcome.

Conclusion: The number of living kidney donations increased significantly after adopting LDN in our series. The equivalent donor/recipient outcome of the LDN series compared with that of previous and ODN series was achieved with increasing experience. [*J Formos Med Assoc* 2009;108(2):135–145]

Key Words: kidney transplantation, laparoscopic donor nephrectomy, living donor, open donor nephrectomy

There has been always a large gap between the number of kidney donors and that of waiting recipients worldwide.[1] The shortage of donor organs can be overcome by increasing the numbers from living and deceased sources. Nevertheless, deceased organ availability has reached a plateau and the demand for organs keeps increasing. In Taiwan, for example, only 150–200 renal transplantations

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Received: March 2, 2008
Revised: April 27, 2008
Accepted: August 6, 2008

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from deceased donors were performed in 2008, although there were over 6500 patients on the waiting list. Therefore, a resurgence of living donors is being observed worldwide as a result of the prolonged waiting time for deceased donors, availability of minimally invasive donor nephrectomy procedures, and significantly better recipient outcomes with living donor kidney transplantation.

Laparoscopic donor nephrectomy (LDN) was introduced for living kidney donors by Ratner et al in 1995.[2] In Taiwan, it has been used since 2002.[3,4] Benefits of the laparoscopic approach include less postoperative pain, shorter hospital stays, faster return to usual activities and work, and improved cosmesis. Since then, LDN has emerged as the preferred technique at many institutions, not only in the United States, but also in other countries.[5–12] It has contributed to a dramatic increase in living kidney donation during the past decade.[13,14] The number of living kidney donations in the United States exceeded the number of deceased kidney donations for the first time in 2001, as reported by the United Network for Organ Sharing.[15]

We adopted LDN in 2002, with the intention of increasing the incentives for living kidney donation and maintaining equivalent donor/recipient outcome with those of previous series and our open donor nephrectomy (ODN) series.

Methods

Between September 2002 and November 2007, 45 LDNs were performed at the National Cheng Kung University Hospital. Preoperative donor evaluation included a medical history review and physical examination, laboratory studies, histocompatibility test and cross-matching, comprehensive renal function tests, and psychosocial evaluation. Renal vascular anatomy of the donors was evaluated using high-resolution computed tomographic angiography with three-dimensional reconstructions.[16,17]

The LDN used in this study was derived from the UCSF (University of California, San Francisco) method.[18] The patient was positioned in a flexed, modified, lateral decubitus position and pneumoperitoneum was achieved using a Veress needle inserted into the left or right pararectus line. Three 11-mm and one 12-mm trocars were introduced into the right or left upper abdomen in a curved L-shape. The 12-mm port was used for introduction of the vascular stapler. Another 11-mm trocar was inserted through the subxiphoid area to retract the liver during right LDN. The entire dissection was completed by a pure laparoscopic method, and care was taken to preserve generous amounts of periureteral tissue to minimize disruption of the ureteral blood supply. Hydration was given during the whole procedure to maintain adequate urine output. When the kidney was fully mobilized, the pneumoperitoneum was relaxed and an 8-cm transverse suprapubic (Pfannenstiel) incision was made. Intravenous furosemide was administered while the abdomen was desufflated. When good diuresis was confirmed, the abdomen was reinsufflated. The distal ureter was double-clipped and transected and the patient was systemically heparinized.[8,9] The renal artery was occluded using a locking plastic clip (Hem-o-lok clip; Weck Closure Systems, Research Triangle Park, NC, USA) and a metal endoclip.[19,20] The artery was divided distal to the clips using laparoscopic scissors. If there were multiple arteries, each artery arising from the aorta was occluded with a locking plastic and a metal clip. The renal vein was stapled using a 2.5-mm vascular stapler (Endo-TA; US Surgical, Norwalk, CT, USA) and divided distal to the staple line using laparoscopic scissors. Heparin sodium was reversed with protamine sulfate and the kidney was removed through the Pfannenstiel incision.

Donor demographic and operative characteristics were gathered from patients' medical records and analyzed retrospectively. The data included donor age, gender, donor/recipient relationship, body height, body weight, body mass index (BMI), side of the nephrectomy, operative time, estimated blood loss, need for blood transfusion, renovascular anatomy, warm ischemia time, and length of postoperative stay. Warm ischemia time was defined as the time from renal artery occlusion to kidney immersion in iced saline solution. Donor/recipient intraoperative and postoperative complications were analyzed. Postoperative donor renal function, graft function, and recipient survival were also evaluated. Postoperative donor renal function and immediate/long-term allograft function were assessed by measurement of serum creatinine levels. Delayed graft function was defined as the need for dialysis because of poor allograft function within the first postoperative week.

To determine the trends of both donor and recipient outcome, the LDN series was divided into earlier (cases 1–20) and later (cases 21–45) groups for comparison. To confirm the safety and efficacy of LDN, we also compared retrospectively the results between LDN and ODN (12 ODNs were performed between 1990 and 2001 in our center).

Statistical analysis

All data were analyzed using SPSS version 11.5 (SPSS Inc, Chicago, IL, USA) for Windows, and data are expressed as percentages or mean ± standard error of the mean. Differences among multiple groups were analyzed using analysis of variance. Tukey's HSD test was used as the *post hoc* test. Differences between two groups were compared using unpaired Student's t test. Linear regression analysis was used to test the independent continuous data. A value of $p < 0.05$ was considered statistically significant.

Results

LDN series

Donor demographics

The donor demographics of the LDN series are listed in Table 1. Mean donor age was 42.7 ± 2.1 years (range, 21–77 years), and eight donors (17.8%) were older than 55 years. Nineteen donors (42.2%) were male and 26 (57.8%) were female. The relationships of donor/recipient pairs were first-degree relatives in 46.6%, second-degree relatives in 26.7%, and spouses in 26.7% of the series. Mean BMI was 24.3 ± 0.5 (range, 16.6–31.9); 25 donors (55.6%) had a BMI > 24 and eight (17.8%) had a BMI > 27. Donor BMI did not affect operative time in our series. Mean human leukocyte antigen mismatch was 2.5 ± 0.3.

Table 1. Donor demographics of the laparoscopic donor nephrectomy series*

Age (yr)	42.7 ± 2.1
Gender	
Male	19 (42.2)
Female	26 (57.8)
Donor/recipient relationship	
First-degree relative	21 (46.6)
Second-degree relative	12 (26.7)
Spouse	12 (26.7)
Body height (cm)	161.9 ± 1.4
Body weight (kg)	64.0 ± 1.8
Body mass index	24.3 ± 0.5
HLA mismatch no.	2.5 ± 0.3

Data presented as mean ± standard error of the mean or n (%).

Operative characteristics of donors

The donor operative characteristics are listed in Table 2. Of the 45 consecutive cases, 41 (91.1%) were left-sided and four (8.9%) were right-sided LDN. Indications for right nephrectomy were all left-sided vascular anomalies (multiple renal arteries). All 45 kidneys were procured and transplanted successfully with adequate renal artery and renal vein length. Mean operative time was 327.7 ± 10.2 minutes (range, 220–537 minutes). Mean estimated blood loss was 286.0 ± 48.3 mL and four donors (8.9%) required blood transfusion. The mean warm ischemia time was 233.9 ± 19.6 seconds. However, warm ischemia time did not correlate with incidence of delayed graft function or recipient serum creatinine levels at any postoperative time. The mean donor postoperative stay was 5.8 ± 0.2 days. Donor postoperative stay did not correlate with donor age, gender, body weight, BMI, operative time, or blood loss. Forty (88.9%) donors had a single renal artery and five (11.1%) had multiple renal arteries. There was a significant increase in intraoperative blood

Table 2. Operative characteristics of donors and corresponding donor/recipient outcome in the laparoscopic donor nephrectomy series*

	Side of kidney donated		Renovascular anatomy		Overall
	Left nephrectomy	Right nephrectomy	Single renal artery	Multiple renal arteries	
Donor	41 (91.1)	4 (8.9)	40 (88.9)	5 (11.1)	45 (100)
Operative time (min)	325.8 ± 11.0	345.5 ± 26.1	318.5 ± 9.6	397.2 ± 39.3	327.7 ± 10.2
Blood loss (mL)	291.0 ± 58.7	237.5 ± 68.8	263.2 ± 43.7	460.0 ± 261.4†	286.0 ± 48.3
Warm ischemia time (s)	232.2 ± 23.6	248.0 ± 52.8	221.2 ± 20.1	341.3 ± 56.1	233.9 ± 19.6
Postoperative stay (d)	5.8 ± 0.2	5.8 ± 0.3	5.8 ± 0.2	5.6 ± 0.2	5.8 ± 0.2
Serum Cr (discharge) (mg/dL)	1.2 ± 0.0	1.2 ± 0.1	1.2 ± 0.0	1.2 ± 0.1	1.2 ± 0.0
Serum Cr ratio (discharge/admission)	1.5 ± 0.0	1.5 ± 0.2	1.5 ± 0.0	1.5 ± 0.1	1.5 ± 0.0
Recipient					
Serum Cr (1 wk) (mg/dL)	1.8 ± 0.3	2.1 ± 0.9	1.9 ± 0.3	1.9 ± 0.7	1.9 ± 0.2
Serum Cr (discharge) (mg/dL)	1.4 ± 0.2	1.4 ± 0.3	1.4 ± 0.1	1.3 ± 0.3	1.4 ± 0.1
Serum Cr (1 yr) (mg/dL)	1.2 ± 0.1	1.6 ± 0.7	1.2 ± 0.1	1.5 ± 0.4	1.3 ± 0.1

**Data presented as n (%) or mean ± standard error of the mean; †$p < 0.05$ compared with single renal artery group by unpaired Student's t test.*

loss in the multiple renal arteries group. Multiple arteries caused by application of the vascular stapler to a renal artery with early bifurcation were found in another three donors. Overall, eight (17.8%) donor kidneys required bench arterial reconstruction by end-to-side anastomosis of a smaller polar artery into the main renal artery ($n = 6$) or by a double-barrel anastomotic technique ($n = 2$).

Donor complications

Intraoperative complications: There were three renovascular injuries (all to the renal vein). Two (4.4%) required open conversion and one was managed laparoscopically. All these cases occurred in the earlier group (cases 3, 9 and 16). Four (8.9%) patients required blood transfusion in the perioperative period. No operations were aborted and the nephrectomies were all performed.

Postoperative complications: There were five cases of lymphatic leakage, one of subcutaneous bleeding, one abdominal wall abscess (over the Pfannenstiel incision), and one case of bacteremia. The overall postoperative complication rate was 17.8%. There were no donor deaths or repeated surgical procedures. None of the laparoscopic donors required readmission.

Postoperative donor renal function

The mean preoperative and postoperative serum creatinine levels of the donors were 0.8 ± 0.0 mg/dL and 1.2 ± 0.0 mg/dL, respectively. Postoperative serum creatinine level at discharge was 1.5 times (range, 1.1–1.9) preoperative serum creatinine level, regardless of donor gender or age (Table 2).

Recipient outcomes

Immediate graft function: Mean recipient serum creatinine level was 1.9 ± 0.2 mg/dL at 1 week postoperatively and 1.4 ± 0.1 mg/dL at discharge. Recipient postoperative renal function did not correlate significantly with donor age, donor gender, or preoperative donor renal function. Primary nonfunction of the renal allograft did not occur in this series and delayed graft function occurred in four of 45 cases (8.9%). The serum creatinine levels of all the other recipients (91.1%) decreased below 3.0 mg/dL at 1 week postoperatively. Mean recipient postoperative stay was 15.9 ± 1.3 days. All but

Table 3. Trends in donor and recipient outcome between earlier and later groups in the laparoscopic donor nephrectomy series*

	Earlier group (cases 1–20)	Later group (cases 21–45)	Overall (cases 1–45)
Donor			
Age (yr)	44.6 ± 3.4	41.1 ± 2.5	42.7 ± 2.1
Gender (M:F)	5:15	14:11	19:26
Body height (cm)	159.1 ± 2.0	164.2 ± 1.9	161.9 ± 1.4
Body weight (kg)	61.1 ± 2.9	66.4 ± 2.2	64.0 ± 1.8
Body mass index	24.0 ± 0.8	24.5 ± 0.6	24.3 ± 0.5
Operative time (min)	344.2 ± 17.0	315.8 ± 12.3	327.7 ± 10.2
Blood loss (mL)	300.0 ± 83.9	276.0 ± 58.6	286.0 ± 48.3
Warm ischemia time (s)	321.0 ± 39.9	177.0 ± 6.2†	233.9 ± 19.6
Postoperative stay (d)	6.3 ± 0.3	5.4 ± 0.2	5.8 ± 0.2
Serum Cr (discharge) (mg/dL)	1.1 ± 0.1	1.3 ± 0.1	1.2 ± 0.0
Serum Cr ratio (discharge/admission)	1.5 ± 0.0	1.5 ± 0.0	1.5 ± 0.0
Intraoperative complications	3 (15)	0 (0)†	3 (6.7)
Postoperative complications	4 (20)	4 (16)	8 (17.8)
Recipient			
Serum Cr (1 wk) (mg/dL)	1.9 ± 0.4	1.8 ± 0.3	1.9 ± 0.2
Serum Cr (discharge) (mg/dL)	1.5 ± 0.3	1.2 ± 0.1	1.4 ± 0.1
Serum Cr (1 yr) (mg/dL)	1.3 ± 0.1	1.3 ± 0.0	1.3 ± 0.1

**Data presented as mean ± standard error of the mean or n or n (%); $^{\dagger}p < 0.05$ compared with earlier group by unpaired Student's t test.*

one patient was discharged with adequate renal function (serum creatinine < 2.5 mg/dL). No recipient mortality occurred in the immediate postoperative period. Kidneys requiring vascular reconstruction ($n = 8$) for multiple renal arteries experienced the same allograft outcomes as those without reconstruction ($n = 37$). The mean serum creatinine levels of the recipients with and without vascular reconstruction at 1 week postoperatively were 1.8 ± 0.5 mg/dL and 1.9 ± 0.3 mg/dL, respectively (p = not significant). The mean serum creatinine levels of the recipients with and without vascular reconstruction at discharge were 1.2 ± 0.2 mg/dL and 1.4 ± 0.2 mg/dL, respectively (p = not significant).

Long-term graft function: Mean recipient serum creatinine levels were 1.3 ± 0.1 mg/dL at 1 year, 1.4 ± 0.1 mg/dL at 2 years, and 1.3 ± 0.2 mg/dL at 3 years postoperatively. There were two (4.4%) recipient deaths. One died of intra-abdominal abscess with sepsis 3 months postoperatively. The other died from intracranial hemorrhage, with a functional graft, 15 months postoperatively. Graft function continues in 41 of the remaining 43 harvested kidneys (95.3%).

Recipient complications

Three (6.7%) recipients had ureteral complications. Two anastomosis leaks occurred secondary to harvest technique and were successfully managed conservatively. One ureteral necrosis, thought to be caused primarily by impaired vascularity of the ureter, was managed by surgical revision of ureteroneocystostomy. No patients developed vascular thrombosis following transplantation.

Trends in donor/recipient outcome

Comparison between the earlier and later groups with regard to both donor and recipient outcome is shown in Table 3. Mean donor operative time in the earlier and later group was 344.2 ± 17.0 minutes and 315.8 ± 12.3 minutes, respectively. The mean estimated blood loss was 300.0 ± 83.9 mL and 276.0 ± 58.6 mL, respectively. The mean warm ischemia time was 321.0 ± 39.9 seconds and 177.0 ± 6.2 seconds, respectively. There was a significant decrease in warm ischemia time in the later group ($p = 0.01$). The mean donor postoperative stay was 6.3 ± 0.3 days and 5.4 ± 0.2 days, respectively. The mean donor serum creatinine level at discharge was 1.1 ± 0.1 mg/dL and 1.3 ± 0.1 mg/dL, respectively. The donor serum creatinine discharge/admission ratio was the same in both groups. There was a significant decline in the rate of donor intraoperative complications in the later group ($p = 0.00$). The mean recipient serum creatinine level at 1 week postoperatively was 1.9 ± 0.4 mg/dL and 1.8 ± 0.3 mg/dL, respectively. The mean recipient serum creatinine level at discharge was 1.5 ± 0.3 mg/dL and 1.2 ± 0.1 mg/dL, respectively. The mean recipient serum creatinine level at 1 year postoperatively was 1.3 ± 0.1 mg/dL and 1.3 ± 0.0 mg/dL, respectively. There was no significant difference between earlier and later groups with regard to postoperative donor and recipient serum creatinine levels.

Comparison between LDN and ODN

Comparison between the LDN and ODN series with regard to donor and recipient outcome is shown in Table 4. Mean donor operative time in the LDN and ODN series was 327.7 ± 10.2 minutes and 246.3 ± 24.4 minutes, respectively. The mean estimated blood loss was 286.0 ± 48.3 mL and 268.2 ± 38.9 mL, respectively. The mean donor postoperative stay was 5.8 ± 0.2 days and 10.3 ± 1.1 days, respectively. There was a significant decrease in donor postoperative stay in the LDN series ($p = 0.00$). The mean donor serum creatinine level at discharge was the same in both series. The donor serum creatinine discharge/admission ratio was 1.5 ± 0.0 and 1.4 ± 0.1 in the LDN and ODN series, respectively. There was no significant difference in donor intraoperative and postoperative complications between both series. The mean recipient serum creatinine level at 1 week postoperatively was 1.9 ± 0.2 mg/dL and 2.2 ± 0.3 mg/dL in the LDN and ODN series, respectively. The mean recipient serum creatinine level at discharge was

Table 4. Comparison between the laparoscopic donor nephrectomy (LDN) and open donor nephrectomy (ODN) series with regard to both donor and recipient outcomes*

	LDN ($n = 45$)	ODN ($n = 12$)
Donor		
Age (yr)	42.7 ± 2.1	48.8 ± 3.4
Gender (M:F)	19:26	4:8
Body height (cm)	161.9 ± 1.4	161.5 ± 2.7
Body weight (kg)	64.0 ± 1.8	65.6 ± 4.3
Body mass index	24.3 ± 0.5	25.0 ± 1.0
Operative time (min)	327.7 ± 10.2	246.3 ± 24.4
Blood loss (mL)	286.0 ± 48.3	268.2 ± 38.9
Postoperative stay (d)	5.8 ± 0.2†	10.3 ± 1.1
Serum Cr (discharge) (mg/dL)	1.2 ± 0.0	1.2 ± 0.1
Serum Cr ratio (discharge/admission)	1.5 ± 0.0	1.4 ± 0.1
Intraoperative complications	3 (6.7)	1 (8.3)
Postoperative complications	8 (17.8)	2 (16.6)
Recipient		
Serum Cr (1 wk) (mg/dL)	1.9 ± 0.2	2.2 ± 0.3
Serum Cr (discharge) (mg/dL)	1.4 ± 0.1	1.6 ± 0.2
Serum Cr (1 yr) (mg/dL)	1.3 ± 0.1	1.6 ± 0.2
Serum Cr (2 yr) (mg/dL)	1.4 ± 0.1	1.5 ± 0.2
Serum Cr (3 yr) (mg/dL)	1.3 ± 0.2	1.4 ± 0.2

Data presented as mean ± standard error of the mean or n or n (%); $^{\dagger}p < 0.05$ compared with the ODN series by unpaired Student's t test.

1.4 ± 0.1 mg/dL and 1.6 ± 0.2 mg/dL, respectively. The mean recipient serum creatinine level was 1.3 ± 0.1 mg/dL and 1.6 ± 0.2 mg/dL at 1 year, 1.4 ± 0.1 mg/dL and 1.5 ± 0.2 mg/dL at 2 years, and 1.3 ± 0.2 mg/dL and 1.4 ± 0.2 mg/dL at 3 years postoperatively. There was no significant difference between the LDN and ODN series with regard to immediate and long-term allograft function.

Discussion

Living kidney donation offers an alternative for individuals awaiting transplantation. It is the predominant source of organs in some developing and developed countries, for example, Egypt and Japan, for legal and cultural reasons.[11,21] At many centers in the United States, approximately 50% of the kidney transplantations performed today are from living donors. In Taiwan, about 30% of the kidney transplantations performed are now from living donors.

With the introduction of LDN, the number of living kidney donors has increased significantly during the past decade. Living kidney donation in the United States, for example, increased from 3668 cases in 1996 to 6563 in 2005.[22] Some studies have revealed that most donors have a positive attitude to the LDN procedures.[14,23]

Living donor nephrectomy is a unique major surgical procedure because it exposes an otherwise healthy patient to the risks of major operation entirely for the benefit of recipients. The steep learning curve of LDN is well known from the experience of institutions with large volumes of patients. Although LDN appears to be relatively low risk for the donor, there are anecdotal and published reports of death attributed to living kidney donation.[24] In a survey of 234 renal transplant programs, Matas et al found two donor deaths and one case of persistent vegetative state, all from hemorrhagic shock, among 10,828 cases.[25] Therefore, donor safety should be the first priority when developing LDN techniques.

The mean operative time in our LDN series was longer than those in the previous series.[5,6,8,9] A mean operative time of 202.1 ± 52.4 minutes in the Maryland series, 252.9 ± 55.7 minutes in the Johns Hopkins series, 196 ± 43 minutes in the UCSF series, and 208.2 ± 55.6 minutes in the Mount Sinai series have been reported. From the experience of the UCSF and Mount Sinai series, the operative time did decrease with experience.[8,9] There was also a trend towards a decrease in mean operative time in our later group, although the difference was not significant. We expect to keep decreasing the operative time as our experience increases. Our series had comparable results with previous series with regard to blood loss and warm ischemia time.[5–7,9] The mean blood loss was 128 ± 194 mL in the Maryland series, 344.2 ± 690.3 mL in the Johns Hopkins series, 197 ± 223.0 mL in the Mount Sinai series, and 286.0 ± 48.3 mL in our series. The mean warm ischemia time was 169 ± 90.8 seconds in the Maryland series, 4.9 ± 3.4 minutes in the Johns Hopkins series, 2.6 ± 0.5 minutes in the Northwestern series, 207.0 ± 91.6 seconds in the Mount Sinai series, and 233.9 ± 19.6 seconds in our series. There was a significant decrease in mean warm ischemia time in our later group. However, warm ischemia time did not correlate with incidence of delayed graft function or recipient serum creatinine levels at any postoperative time in our series, which was similar to the findings of the other series.[26,27]

LDN is quite challenging in obese donors, who most benefit from the procedure with regard to wound and pulmonary complications. There are cumulative data in the literature indicating that LDN can be performed safely in obese donors.[28] In our series, 25 donors (55.6%) had BMI > 24 and eight (17.8%) had BMI > 27. Although operation on obese donors certainly increases the stress on the surgeon, it did not take longer operative time, increase operative complications, or need any technical modifications in our series.

Three-dimensional computed tomographic angiography was routinely performed on all our donors preoperatively to help identify renal vascular anatomy, including the number of main renal vessels, presence of branches of renal vessels, and the relationship between each vessel. In our series, 11.1% of the donors had multiple renal arteries, in contrast to 17% in the UCSF series and 23% in the Northwestern series.[7,8] The higher rate of multiple renal arteries in the Northwestern series may have been caused by the higher rate (99%) of left donor nephrectomy in that series. Two (40%) of the cases with multiple renal arteries in our series were identified preoperatively and three (60%) were identified intraoperatively. We took every effort to preserve all branches, no matter whether they were main or polar branches. There was a significant increase in intraoperative blood loss in the group with multiple renal arteries. Operative time and warm ischemic time were longer in the multiple renal arteries group, although there was no significant difference. Another three cases resulted from the application of the vascular stapler to a renal artery with early bifurcation. We found that this was most likely to arise if the bifurcation was < 1 cm from the aorta junction. Overall, 17.8% of donor kidneys required bench arterial reconstruction by end-to-side anastomosis or double-barrel anastomosis. Kidneys that required vascular reconstruction experienced similar allograft outcomes, both immediate and long-term, to those without reconstruction.

It has been reported that right LDN has a higher rate of delayed graft function and vascular thrombosis caused by a short renal vein, and several groups have avoided or abandoned the performance of this procedure.[29,30] With improved technique and increasing experience, right LDN can be performed safely with excellent graft outcomes and low donor morbidity.[31–33] Left donor nephrectomies were performed in 96% of donors in the Maryland series, 95% in the Johns Hopkins series, 99% in the Northwestern series, 84% in the UCSF series, 86% in the Mount Sinai series, and 91% in our series.[5–9] With more experience, right LDN and donors with complex renal vessels can be managed with fewer complications. Some centers prefer to choose the right kidney when vascular anomalies are present in the left kidney, and accept the shorter length of the right renal vein. Other centers prefer to choose the left kidney and reconstruct multiple vessels for implantation. We selected the side of nephrectomy based on the same criteria used in open operation, which is similar to the experience of the UCSF and Mount Sinai series.[8,9] There was also no significant difference in donor operative time, blood loss, warm ischemia time, postoperative stay, and complications between our right-sided and left-sided groups (Table 2).

The occurrence of major vascular complications that require conversion to open surgery is unique to the laparoscopic approach. Such complications are more readily managed during the open approach and may not always be reported. Our experience is similar to those of previous series; most open conversions are the result of renovascular injuries and happen in the earlier period. Three renal vein injuries occurred in our earlier group and two were caused by overtraction. We used to place vessel loops around each major vessel to facilitate traction during hilum dissection and help identify the vessels during posterior dissection of the kidney. However, forced traction leads to disruption of the lumbar veins and, finally, open conversion. This was discovered by postoperative video review and did not happen again in our later group after applying gentle traction of vessel loops.

One of the major reasons for renovascular injuries is device failure and misapplication, which may lead to catastrophic bleeding and potentially donor death.[34] We adopted the UCSF method to manage the renal vessels: the renal artery was occluded using a locking plastic clip and a metal endoclip, and the renal vein was stapled using an Endo-TA stapler. These techniques essentially separate vessel occlusion and vessel transection, which allows careful visualization of the arterial and venous ligation before transection. An added benefit of this technique is to obtain additional vessel length with fewer staple lines than with the GIA (gastrointestinal anastomosis) stapler. Using these methods, we did not experience any significant bleeding caused by device failure and misapplication.

Bowel complications have also been reported during the laparoscopic approach. In the Maryland series, five small bowel obstructions were reported that required laparotomy.[6] In the Johns Hopkins series, there were five bowel injuries, including one duodenal injury, three small bowel injuries, and one colon injury.[5] In the UCSF series, there were two small bowel injuries and one bladder injury.[8] We did not observe any bowel complications in our series. To avoid the risk of bowel injuries during laparoscopic dissection, direct manipulation of the bowel should be minimized and blunt instrumentation should be used for retraction. It is also important to be well aware of the anatomy during dissection of renocolic and renosplenic planes, in order not to create mesocolic defects, and splenic and pancreatic injuries.

Chylous ascites is a potential complication of LDN because of dissection and division of the lymphatics adjacent to the renal hilum. We began to notice chylous ascites in the middle period of our series. Increasing experience encouraged us to do more extensive dissection and to acquire maximal vessel length, which contributed to this complication. Thereafter, we modified our technique to a less extensive but adequate dissection and have not observed such complications again.

The Maryland series reported that donor mean postoperative serum creatinine level was 1.5 times higher than the preoperative level.[6] The Northwestern series reported that the donor preoperative and postoperative day 7 serum creatinine levels were 0.9 ± 0.2 mg/dL and 1.3 ± 0.3 mg/dL, respectively.[7] Our series had a similar result in that the preoperative and postoperative donor serum creatinine levels were 0.8 ± 0.0 mg/dL and 1.2 ± 0.0 mg/dL, respectively. The donor postoperative/preoperative serum creatinine ratio was 1.5 ± 0.0.

Graft function and recipient survival should be taken into consideration when assessing this innovative laparoscopic technique. The Maryland series reported that recipient serum creatinine level averaged 2.0 ± 1.5 mg/mL at 1 week and 1.7 ± 1.1 mg/mL at 1 month postoperatively.[6] However, 13.3% of recipients did not achieve a serum creatinine level of < 3.0 mg/mL within 7 days. The Johns Hopkins series reported that recipient serum creatinine level averaged 2.6 ± 2.3 mg/dL at 4 days after operation, which is similar to that in the open group.[5] The Northwestern series reported that recipient serum creatinine level averaged 1.5 ± 0.2 mg/dL at 1 week.[7] The Mount Sinai series reported 3.0% delayed graft function and 2.5% graft loss.[9] In our series, recipient serum creatinine level averaged 1.9 ± 0.2 mg/dL at 1 week postoperatively and 1.4 ± 0.1 mg/dL at discharge. Primary nonfunction of the renal allograft did not occur and delayed graft function occurred in four of 45 cases (8.9%). All but one patient was discharged with adequate renal function. No recipient death occurred in the immediate postoperative period. With regard to immediate graft function, we had comparable results to those of the previous series.[5–7,9]

The Maryland series reported that recipient serum creatinine level averaged 1.6 ± 1.4 mg/mL at 1 year, 1.9 ± 1.4 mg/mL at 2 years, 1.7 ± 1.0 mg/mL at 3 years, and 1.7 ± 0.7 mg/mL at 4 years.[6] The Johns Hopkins series reported that recipient creatinine clearance averaged 65.5 ± 25.8 mL/min at 5 years, which was similar to that in the open group.[5] The Northwestern series reported that graft function continued in 481/500 (96%) kidneys during follow-up.[7] In our series, recipient serum creatinine level averaged 1.3 ± 0.1 mg/dL at 1 year, 1.4 ± 0.1 mg/dL at 2 years, and 1.3 ± 0.2 mg/dL at 3 years. Graft function continued in 41 of the 43 harvested kidneys (95.3%). With regard to long-term graft function, we also had comparable results to those of the previous series.[5–7]

Previous studies have shown a significantly higher rate of ureteral complications in transplant recipients with the laparoscopic approach in early experience.[5] With evolution of the ureteral dissection technique, this problem seems to have been solved. In our current technique, soft tissue around the ureter was preserved as much as possible in order not to injure the blood supply of the ureter. We clipped and transected the gonadal vein at the level of ureter division. We routinely stented the ureter in the recipient operation and removed it 1 week later. The Maryland series reported 33/730 (4.5%) cases of ureteral necrosis/ischemia, the Johns Hopkins series reported 24/381 (6.3%) ureteral complications, and the Northwestern series reported only 1/500 (0.2%) patients with ureteral stricture.[5–7] In our series, 3/45 (6.7%) recipients had ureteral complications and only one (2.2%) had ureteral necrosis that was thought to be caused by the laparoscopic procedure. With regard to ureteral complications, we had comparable results to those of the previous series.[5–7] Technical-related vascular thrombosis is another serious complication that can result in graft loss. The Johns Hopkins series reported 8/381 (2.1%) cases of vascular thrombosis, and the Northwestern series reported 4/500 (0.8%) recipients with vascular complications, including two with renal artery thrombosis.[5,7] We did not have any cases of vascular thrombosis and attributed this to routine systemic heparinization before division of renal vessels.

The UCSF series reported a significant decrease in operative time with experience.[8] The Johns Hopkins series reported a significant decline in total donor complications, ureteral complications, allograft loss, and vascular thrombosis with increasing experience.[5] With more experience and specific evolution in surgical techniques, we achieved a significant reduction in donor intraoperative complications and warm ischemia time in the later group. Although there were no significant differences, the operative time, estimated blood loss and donor postoperative complications also declined in the later group. The most likely explanation for these observations is the steep learning curve for LDN, which requires a greater number of patients to reveal the progress made.

A few randomized studies have compared LDN and ODN.[35–37] Øyen et al concluded that despite ODN being a very secure procedure regarding donor safety, a perfect, uncomplicated LDN appears to be the superior procedure.[37] The equivalent renal graft function between LDN and ODN has also been documented.[38,39] In our series, the operative time in the LDN series was longer than that in the ODN series, although there was no significant difference. The LDN series had a significantly shorter donor postoperative stay than that in the ODN series, as expected. Both series had equivalent results with regard to donor safety, donor outcome, and immediate and long-term allograft function. Before 2002, we had only 12 living kidney donors who received ODN in 12 years (1990–2001). The number of living kidney donors increased significantly after we adopted and developed LDN after 2002 (45 cases, 2002–2007). The percentage of living/all kidney donations in our center increased from 13.5% before 2002 to 56.5% after 2002. In these years, the percentage of living kidney donation in Taiwan was around 30%. From our experience, it is expected that the number of living kidney donations will keep growing with the popularization of LDN.

In conclusion, the number of living kidney donations increased significantly after adopting LDN in our series. An equivalent donor/recipient outcome in the LDN series to that in the previously reported series and our ODN series was achieved with increasing experience.

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